

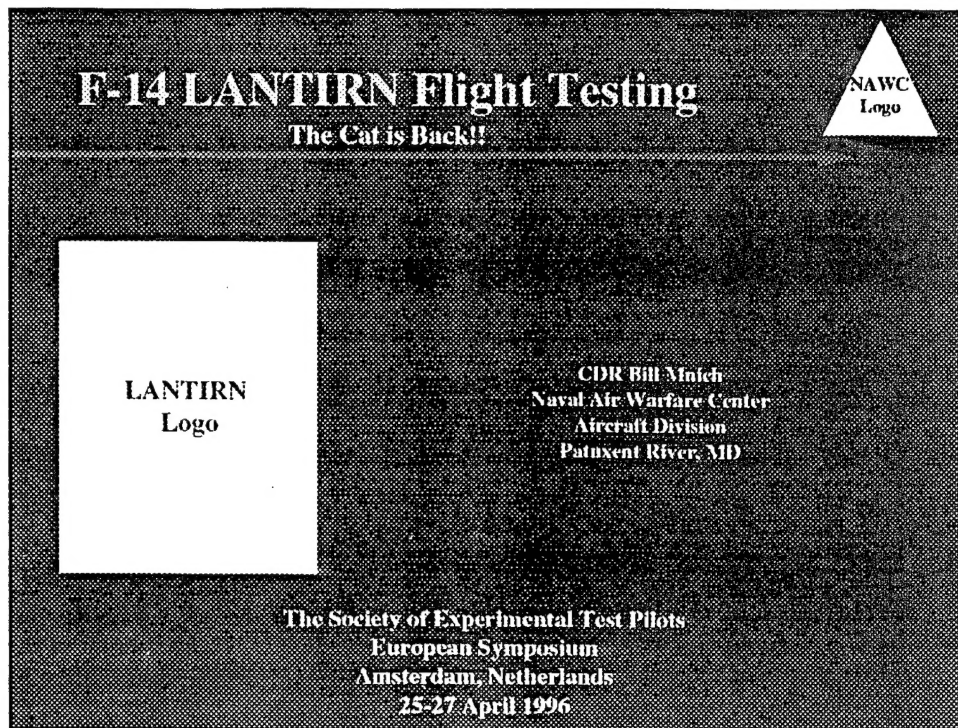
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13. ABSTRACT (Maximum 200 words) I'm sure that most of you are aware of the Tomcat's well-deserved reputation as a world-class air-superiority fighter. However, after my presentation today, I hope you will agree that it has also become a very effective strike aircraft as well. I'll trace this fairly recent evolution from fighter to strike-fighter, and focus specifically on how we qualified an Air Force System - the LANTIRN targeting pod - on a carrier-based Navy jet.				
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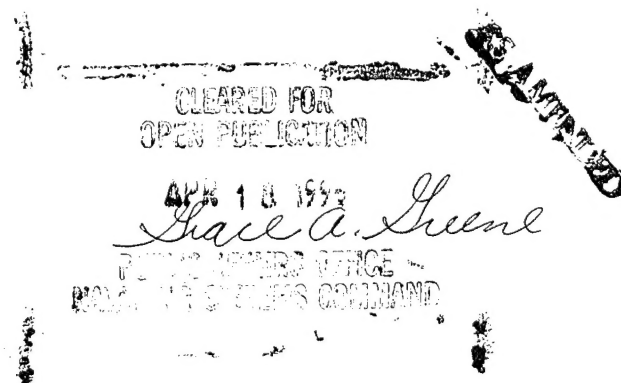
Good afternoon ladies and gentlemen.

I appreciate the opportunity to speak to you today about a series of flight tests that we just concluded a few weeks ago.

I'm sure that most of you are aware of the Tomcat's well-deserved reputation as a world-class air-superiority fighter. However, after my presentation today, I hope you'll agree that it has also become a very effective strike aircraft as well.

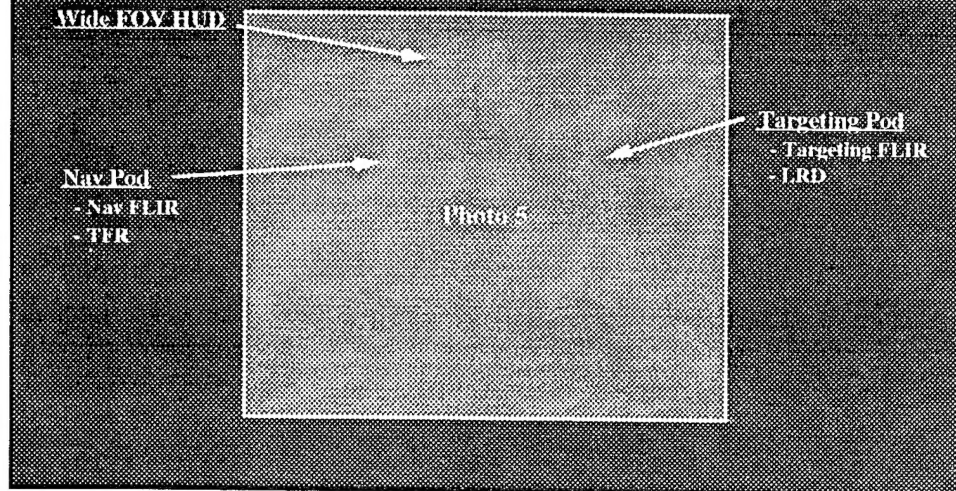
I'll trace this fairly recent evolution from fighter to strike-fighter, and focus specifically on how we qualified an Air Force system - the LANTIRN targeting pod - on a carrier-based Navy jet.

First of all, I'd like to provide a brief introduction to the LANTIRN system...



F-15E LANTIRN System

Low-Altitude Navigation/Targeting Infrared for Night



...Low-Altitude Navigation/Targeting Infrared for Night...

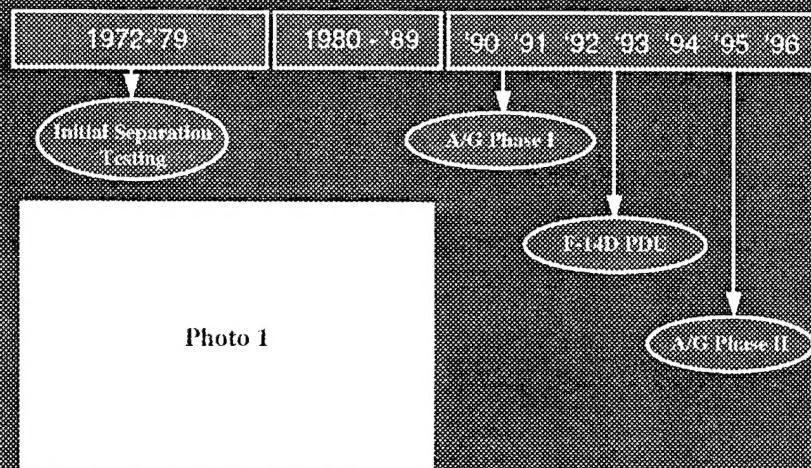
The system is currently operational on both the F-15 and F-16. Shown here on the Strike Eagle are the key elements of LANTIRN, which features two independent pod-mounted sensors. On the left side is the Navigation pod containing both the Terrain-Following Radar and Navigation FLIR, images from which can be presented to the pilot on the Wide FOV raster HUD for low-level navigation. The targeting pod is carried on the other side, and incorporates the targeting FLIR and laser rangefinder systems.

With the full two-pod system, the F-15E can perform the low-altitude strike mission day or night in almost any weather conditions. It's a magnificent weapons system with an outstanding combat record, and was one of the stars of Desert Storm.

Unfortunately, the F-15 can't land on an aircraft carrier.

So, why did the Navy decide to incorporate the LANTIRN targeting pod on the F-14, and how did we do it?

F-14: Tomcat to "Bombcat"



First, a bit of background...

The photo shown here was taken roughly 20 years ago, and illustrates the original intention for the F-14 to deliver air-to-ground ordnance. Initial separation tests were conducted in the mid-70's, but unfortunately, low ejection velocities from the bomb racks available at that time resulted in poor separation characteristics and bomb-to-bomb collisions.

Following these tests, we spent the last 15 years of the Cold War almost exclusively in the air-to-air role. However, with the demise of the "Evil Empire", the events of Desert Storm, and the imminent retirement of the venerable A-6 Intruder, our mission priorities changed somewhat.

In 1990, with the availability of the BRU-32 bomb rack for the F-14 and its higher ejection velocities, Pax River began a series of separation programs designed to resurrect the Tomcat's latent air-to-ground talents. Those programs were called Air-to -Ground Phase I, the F-14D Pre-Deployment Upgrade, and Air-to-Ground Phase II.

Weapons Separation Programs

- 1990-'91: Air-to-Ground Phase I (F-14A/B)
- 1992-'93: Pre-Deployment Upgrade (F-14D)
- 1995: Air-to-Ground Phase II (F-14A/B/D)

Photo 2

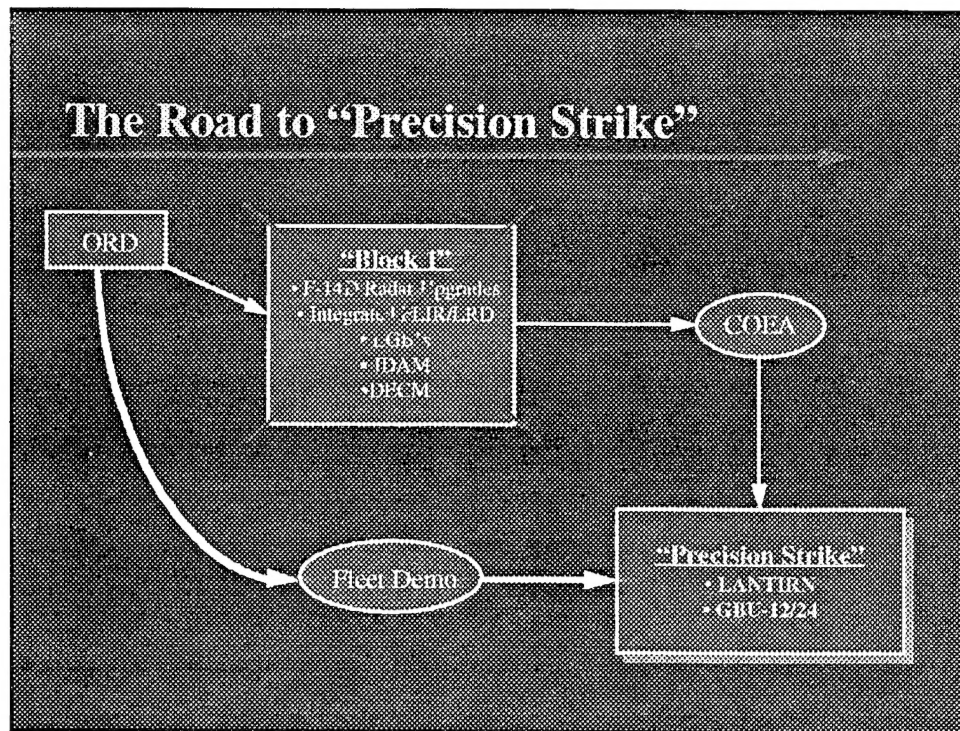
Photo 3

Photo 4

Phase I of the Air-to-Ground separation program cleared the F-14A/B for Mk.80 series weapons, Rockeye, GBU-10, GBU-16 and many others (TALD, LGTR, Mk 58 MLM, LUU-2 Paraflare, BDU-48 HD Practice bombs).

Next, the PDU program added basic Mk.80 series weapons to the F-14D arsenal, and just last December, we concluded Phase II of the Air-to-Ground program, which further expanded F-14A/B capability and essentially brought the 'D' up to that same level.

All of this proved necessary, but still not sufficient to meet fleet requirements. Although the Tomcat could now drop both "dumb bombs" and precision guided munitions, and in fact did so in Bosnia using buddy lasing from an F-18, it still lacked a self-contained targeting capability...



In May of 1993 an Operational Requirements Document was issued that formalized this requirement. The ORD led to a \$1.6B new-start program called Block 1, some elements of which are shown here. When Block 1 was cancelled for budgetary reasons in 1994, a study (the COEA) was commissioned which determined that the most cost-effective way to meet the ORD was to incorporate a FLIR/Laser Designator system with LGB's.

In the meantime, the Commander, Naval Air Forces Atlantic Fleet sponsored an independent initiative to demonstrate a stand-alone LANTIRN targeting pod on an F-14B. This Demo program indicated that excellent results could be achieved at low cost, in minimal time, with very simple aircraft modifications.

It was primarily the fleet demo, and to a lesser extent the COEA results, that shaped the program we now call "Precision Strike".

Now, let's take a closer look at the demo...

LANTIRN Fleet Demo

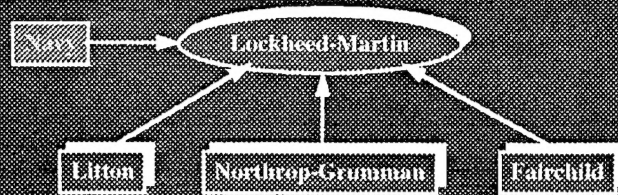
- ◆ Sponsored by COMNAVAIRLANT
- ◆ Lockheed-Martin Proposal:
 - Modified LANTIRN Targeting Pod
 - A-12 Hand Controller
 - F-14B Baseline
- ◆ Results
 - 16 Drops, 14 Bullseyes!

This was a rapid-prototyping exercise sponsored by Naval Air Forces Atlantic and supported with company funds by the Lockheed-Martin Corp, makers of the LANTIRN system. The design concept featured the LANTIRN *targeting* pod modified with an internal GPS/INS navigation system, an A-12 hand controller (one of the few things of value the Navy retained from that program!), and an improved rear cockpit display that was already being introduced in fleet aircraft. These systems were used in a one-off installation on a Fleet F-14B, and the results speak for themselves. Four of those 16 drops were done using live ordnance, and I'd like to show you one of them.

(VIDEO CLIP #1)

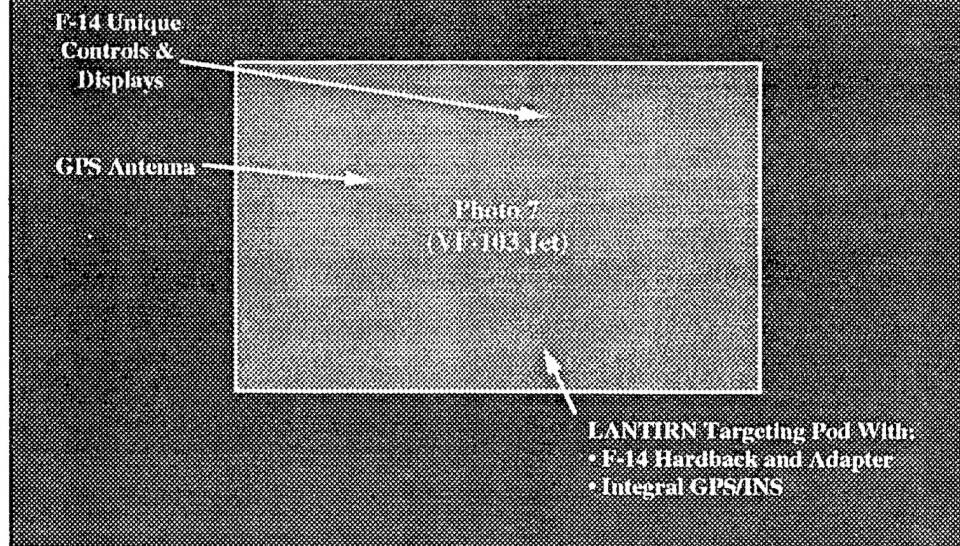
This is a GBU-16 1000 lb LGB being dropped on the Vieques target range near Puerto Rico.

LTS Development Team



Once the Precision Strike program was given a final go-ahead by the Naval Air Systems Command, the system architecture used in the demo was productionized and became known as the LANTIRN Targeting System, or LTS. With Navy oversight, the Lockheed-Martin Corp. acted as the prime contractor, responsible for the pod, mounting hardware, and overall system performance. Litton was selected to manufacture the embedded GPS/INS system in the pod. Northrop Grumman was responsible for the design and installation of the aircraft wiring mods and GPS antenna, and Fairchild Defense Systems developed the LANTIRN Control Panel, or LCP, for the back seat.

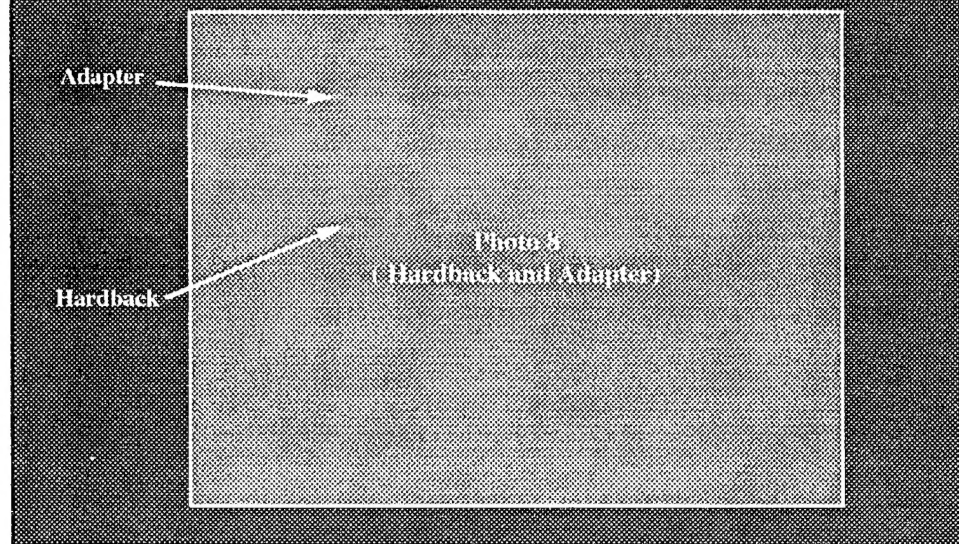
F-14 LTS Design



Here's a look at the key elements of the LTS.

I want to stress once again that this is essentially a hard-wired system. It has virtually no interaction with aircraft mission computer software other than to recognize the weapons and waypoint coordinates entered and selected by the aircrew. All navigation functions, target cueing and weapon ballistics are computed in the pod, and displayed to the aircrew on a head-down presentation selectable by both the pilot and RIO.

F-14 Mounting Hardware



The mounting hardware consists of a unique hardback specifically designed for F-14 use, and a modified version of the pylon adapter used during the PDU program.

AN/AAQ-14 LANTIRN Targeting Pod

Photo 6
(Pod With Pilot)

✧ Dimensions

- Length: 7 ft 6 in
- Weight: 560 lbs

✧ Optics

- 5.87° Wide FOV
- 1.65° Narrow FOV
- 0.825° Expand

✧ Laser Ranger/Designator

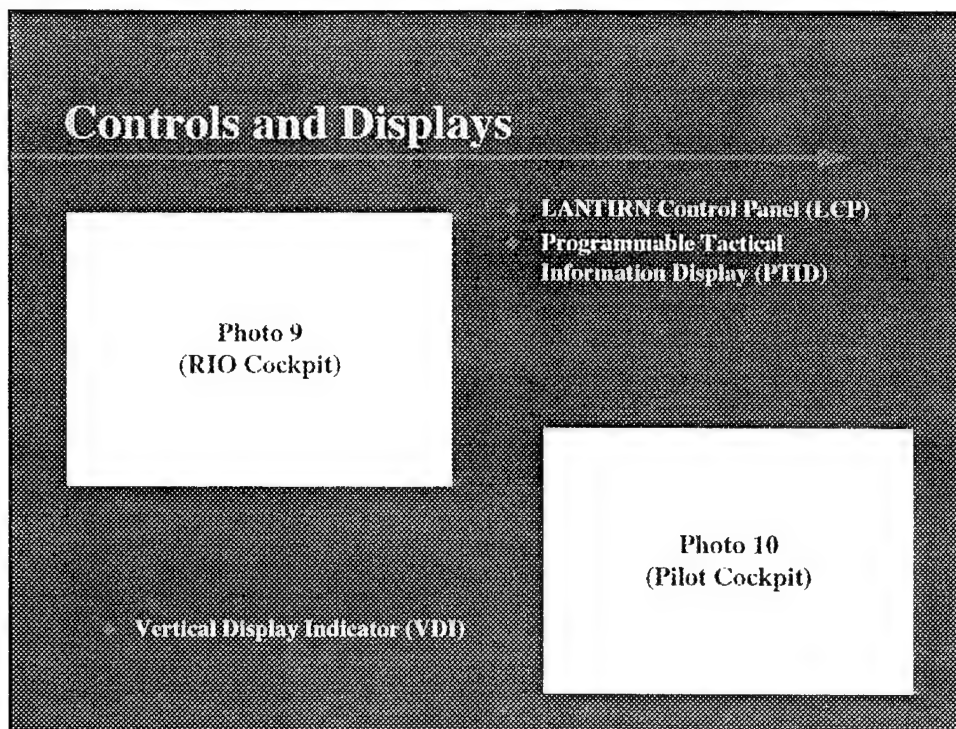
- 1.54 μm Training (Eye-Safe)
- 1.06 μm Combat

Here are some vital stats on the pod.

Note the 50th percentile LT shown here for scale...

A notable feature of the LANTIRN Targeting pod is the existence of a ground-selectable eye-safe training mode for the laser, enabling the aircrew to gain valuable experience with the system virtually anywhere without the requirement for a sanitized training range.

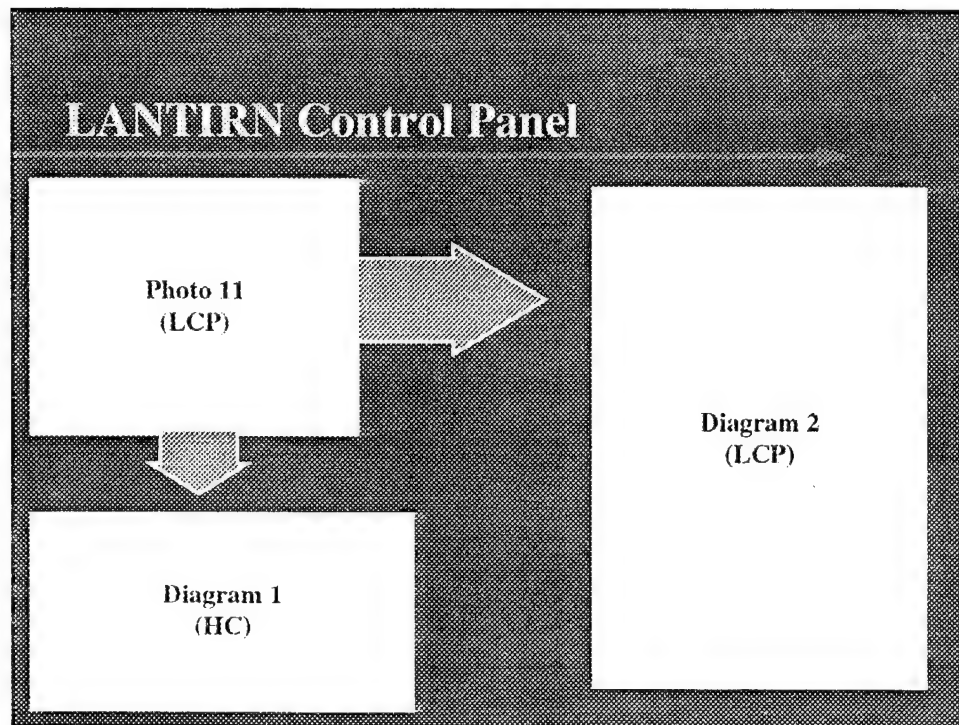
Controls and Displays



The primary LTS presentation is on the Programmable Tactical Information Display, or PTID, in the RIO cockpit. Manufactured by Loral, the PTID provides an 8X8 inch square monochrome display that can display both stroke and raster. It is fully sunlight-readable and replaces the existing Tactical Information Display (TID), which is a late 60's technology design that has always had very poor sunlight readability and has reached the limit of its growth capability.

Also shown in the upper photo is the location of the LCP on the RIO's left console.

There are no LTS-unique controls or displays in the front seat, but the pilot can select the FLIR presentation on his Vertical Display Indicator (VDI).



The LCP contains all the cockpit controls necessary for the RIO to operate the LANTIRN Targeting System. On the hand controller itself, there are 8 individual shape-coded switches that permit hands-on selection of all tactical functions of the pod and laser system. The panel also contains a lever-locked laser arm switch, status indications, BIT advisory lights, a video source selector button for the PTID, and an Initiated BIT selector button. All backlighting on the production LCP's will be NVG-compatible.

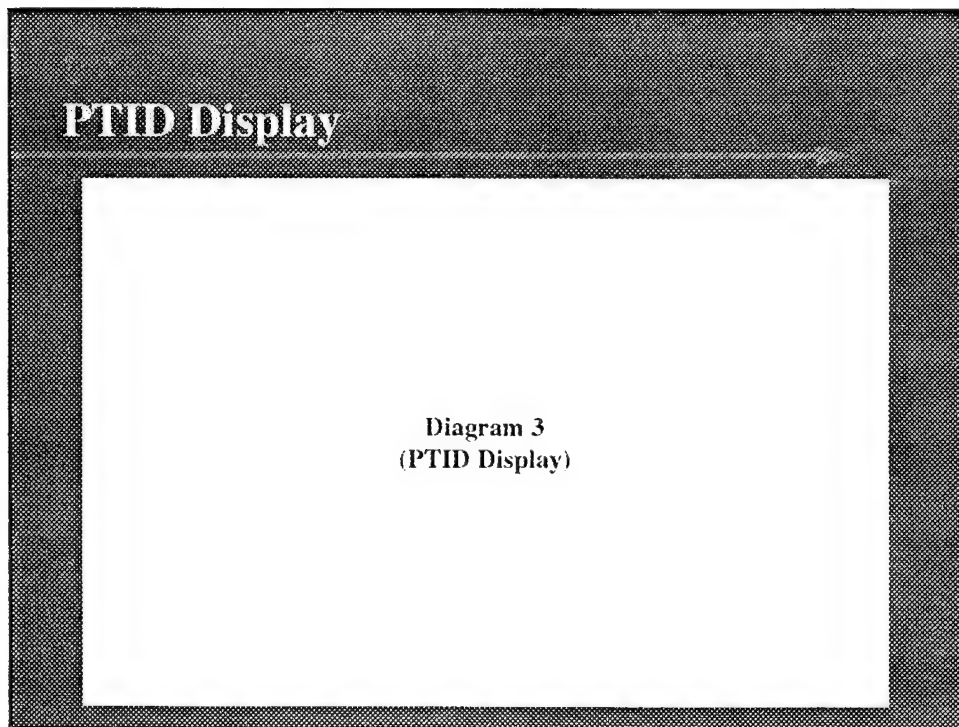


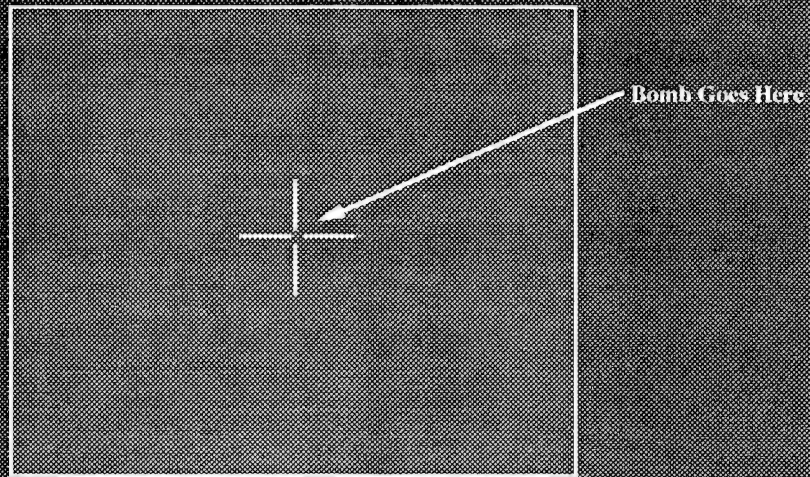
Diagram 3
(PTID Display)

Here's your eye chart for today.

As you can see, there's a lot of information on this display. We have target data down here in the lower right, GPS status and pod line-of-sight information in the lower left, own aircraft information up here, a graphic steering error bar, release cue, pod status indications, etc.

Although the Lieutenants understood all this stuff, it proved a bit much for *me* to assimilate. So, in an effort to clear up my own confusion, I searched through the LANTIRN User's Guide and found a special supplement for Commanders and above.

PTID Display



And this is pretty much all I needed to know about system operation!

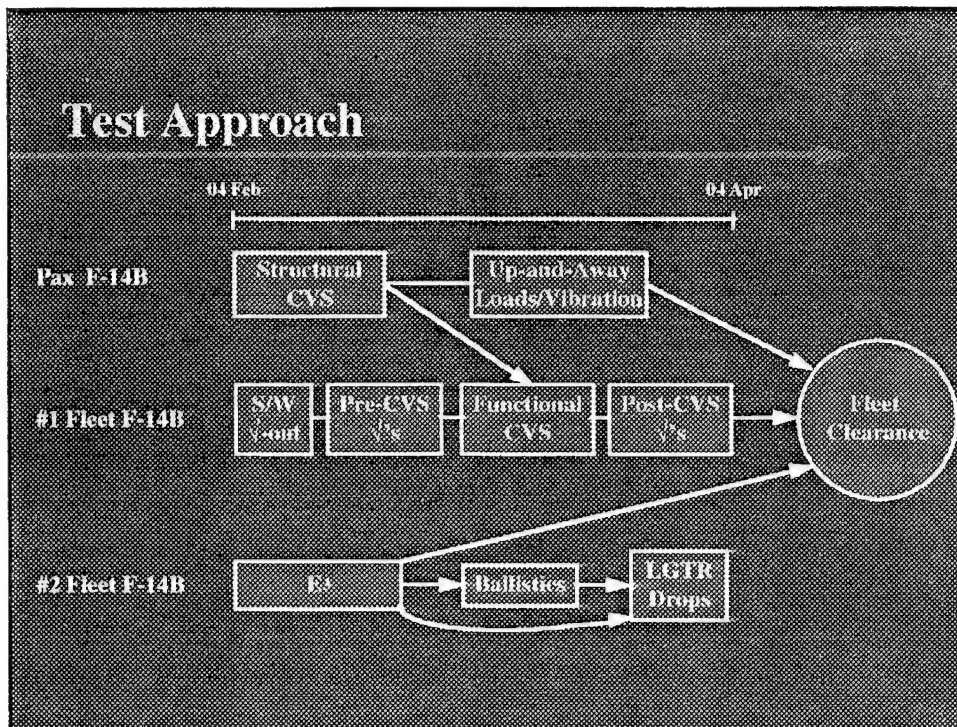
Programmatics...

- ◆ **Tight Budget**
- ◆ **Aggressive Schedule**
 - **Contract Award Oct 1995**
 - **Hardware Available Jan - Feb 1996**
 - **DT Opportunity Window Jan - Mar 1996**
 - **Fleet Training Apr - May 1996**
 - **Deployment USS Enterprise Jun 1996**
- ◆ **Flag-Level Interest**

One of the key attributes that influenced production approval of the LTS was affordability. The entire program was built around a \$300M budget for aircraft modifications and the procurement of 75 systems, which represents a rather high "Bang-to-Buck" ratio.

The other critical element was schedule. A requirement was established by operational commanders that the system must be available for deployment on Enterprise in late June of this year, and all of our planning was based on that deadline. This drove the design and development of both the hardware and software to a critical path schedule that we expected from the beginning would be ambitious. It's impressive to note that the contractor team moved from system design to first article production in less than four months. Equally impressive is that we will have gone from contract award to deployment in 7 months!

Not surprisingly, as a result of world events in the Eastern Mediterranean and Bosnia, there was considerable high-level interest within the Navy in seeing this system fielded on schedule.



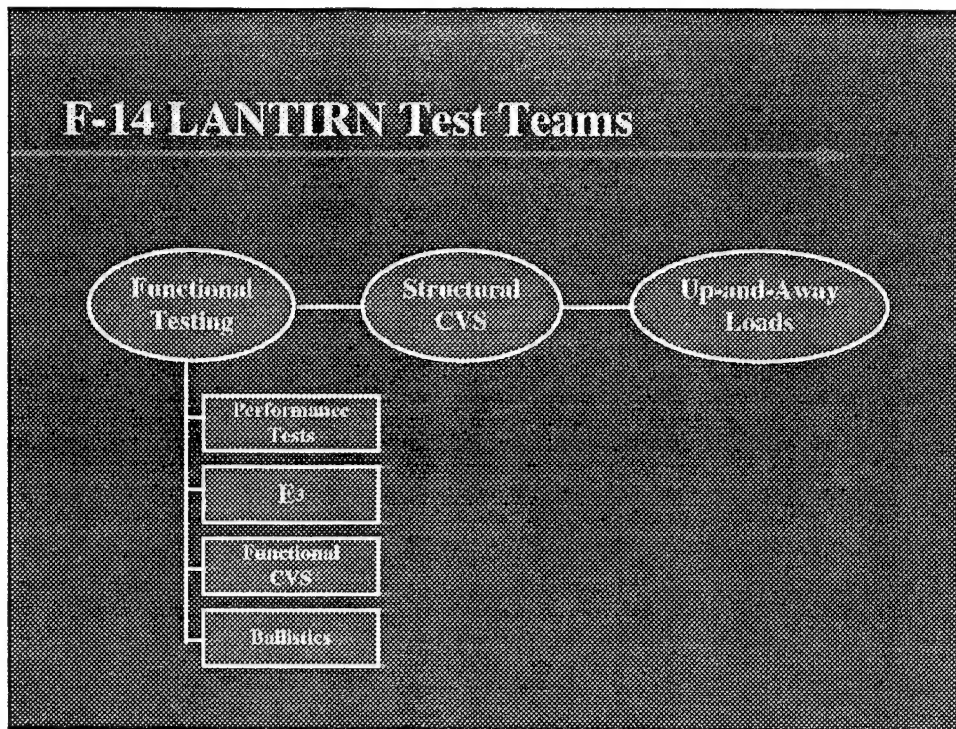
So, our challenge was to thoroughly test the performance of the LTS, qualify it for the rigors of aircraft carrier operations and the F-14 flight environment, and oh by the way, do it in three months. At least that's what we thought... even before we began our testing, delivery dates for some critical elements of the hardware, namely the LCP and PTID, had slipped by several weeks.

This chart illustrates some of the complexities built into our test approach in order to meet the schedule. For example, the same instrumented F-14B, pod and hardback were required for the Structural Carrier Suitability and Up-and-Away Loads and Vibration tests, so these events had to occur in series.

Completion of the Structural CVS was a prerequisite to the Functional CVS, which tested a fully operational system installed on a LANTIRN-configured fleet F-14B. For schedule purposes, the Electromagnetic Environmental Effects (E-Cubed) had to be performed in parallel, and this required us to take custody of a second fleet F-14B that was initially dedicated to this purpose. Successful completion of E-Cubed was necessary to permit the carriage of jettisonable stores, which meant scheduling the LGTR drop at the end.

All totalled, there were 7 individual flight clearances required at specific points during the flight test program to keep everything on track.

F-14 LANTIRN Test Teams



Because of the different engineering disciplines involved and the fact that so many elements of the test effort were occurring in parallel, it was necessary to organize into individual test teams. This graphic shows the general breakdown of those teams.

Each team was headed up by a project officer and flight test engineer, and each was comprised of both government and contractor personnel from the same area of expertise.

My job was to coordinate all this talent, which meant that I was probably the only one on the program who didn't do any *REAL* work.

Now, I'd like to talk briefly about some of the ground testing...

Ground Tests

- E3
- Laser Masking
- Static MR&T
- Static Laser Borelight
- Buss Loading
- S/W Regression
- Mil-Std-704 Compliance
- TCS Video Jumper

Photo 12
(Laser Masking Test)

All the events listed here are only a subset of the many ground tests performed throughout the course of the program. In fact, almost the entire month of February was strictly devoted to system checks, and first flight of an operational LTS on one of the fleet aircraft was not until 28 February.

This photograph shows the set-up used to verify the laser masking curve in the pod software, which will be the same for all F-14 variants. We didn't have the luxury of an adaptive capability that would account for the actual stores loaded on the aircraft, so Lockheed Martin simply coded the masking curve to assume the worst case condition. This was an F-14D with its Dual Chin Pod, a GBU-10 on the forward right belly station, and a Sidewinder missile adjacent to the LANTIRN pod.

By the way, we don't know yet if we can actually shoot this Sidewinder without damaging the pod, and there are presently no plans to conduct a flight test!

Flight Tests

- **Structural CVS**
- **Functional CVS**
- **Up-and-Away Loads and Vibration**
- **Functional Testing**
 - **Fam: S/W Checkout**
 - **Pre/Post CVS MRAT**
 - “ “ **Laser Boresight**
 - **NVG Compatibility**
 - **Ballistics Verification**
 - **Final End-to-End √ : LGTR Deliveries**

Now, on to the fun stuff.

The Structural Carrier Suitability and the Up & Away Loads tests were performed on a fully instrumented F-14B, while all the Functional testing, including the functional Carrier Suitability, was done using the two fleet F-14B's we borrowed from Fighter Wing Atlantic in Oceana, VA. These were the first of ten squadron aircraft to receive the LANTIRN modification prior to their deployment on Enterprise.

Structural CVS

- 7 Flights; 14.0 Flt Hrs
- Instrumented Pax F-14B
- Instrumented LANTIRN and Hardback
- 5 Cats
- 12 Traps
- 58 (!) High-Sink Touch-and-Go's

Photo 13

The Structural Carrier-Suitability tests utilized the TC-7 Steam Catapult and Mk. 7 arresting gear facilities built into Runway 32 at Pax River. This is our F-14B shown here being lined up for one of the five cat shots in the series.

For all of these tests, we had real-time monitoring in the ground station of landing gear drag brace loads, oleo position, launch bar and tailhook axial loads, aircraft accelerations in all 3 axes, and a total of 40 strain gauges and accelerometers mounted on the pod and hardback.

Structural CVS Results

Cats	Test Point	Target	Actual
	Max g	4.6	4.3
	Off Center	6"	6"
Traps	Max g	4.15	4.2
	Off Center	20 R/L/R	21 R/L, 23 R/R
	Roll / Yaw	5° / 5°	4.5° R / 4.4° NR
	Roll / Yaw Opp.	5° / 5°	5.2° R / 6.7° NR
	Free Flight	Yes	Yes
T & G's	Nominal Att.	1248 rpm	1320 rpm / 6° GS
	Nose-Down Att.	1248 rpm	1230 rpm / 6° GS

This table shows some of the endpoint data from the LANTIRN Structural Carrier Suitability. Other than the "nose-down" touch-and-go's (which really means a reduced nose-*UP* attitude - in other words we still landed on the main gear first!) this is a standard set of test events used to qualify any new component on the F-14. These so-called "nose-down" points were performed because slightly higher pod loads were predicted in this attitude.

You'll note that there are some exceedances here, but all were within allowable overshoot tolerances granted in the flight clearance with the exception of the max g arrestment point. That one required us to temporarily stop the test until we consulted with our clearance authority and got a thumbs-up from them. Of course, all of these max g numbers refer to values in the +/- Nx direction.

The slight undershoot in the max g catapult test point was due to a high headwind component that day, which meant that we had to reduce the acceleration slightly to avoid exceeding a limitation on max excess speed at the end of the catapult stroke.

Structural CVS Results (cont'd)

Diagrams 4/5 (Drag Brace Loads Data Plot)

We observed an interesting anomaly during the high sink rate touch-and-go's. The data plot on the right is a characteristic time history of the normal "Spin-up/Spring-back" loads observed in the F-14 Main Landing Gear drag brace at touchdown. Although this occurs even during a field landing, it is greatly exaggerated by the very coarse-textured "non-skid" coating applied to the deck of an aircraft carrier.

On the left you see cumulative (peak to peak) drag brace loads shown as a function of touchdown sink speed for two different conditions:

First, the data shown in red were taken when the starboard main landing gear oleo strut was within its normal 224-day servicing cycle. These are significantly higher loads than expected, and in turn were generating unusually high loads within the LANTIRN pod. More significantly, the trend line indicated an exceedance of drag brace ultimate load at less than maximum aircraft sink speed, and this condition could easily be reached on a fleet aircraft with a hard shipboard landing.

In an effort to isolate the problem, we decided to completely deservice and then reservice both main landing gear oleo's in accordance with the 224-day servicing procedure. As indicated by the blue squares, this immediately reduced the drag brace loads (and pod internal loads) to well within the normal range.

As a result of this finding, we are planning a series of tests to determine what changes may be necessary in existing maintenance procedures or servicing intervals for the main landing gear.

Functional CVS

- 2 Flights; 5.4 Flt Hrs (1 Day !)
- Fleet F-14B
- Fully Functional LTS
- 6 Cats
- 5 Traps
- 9 High-Sink Touch-and-Go's
- IBIT and Pod Functional ✓
- Between Each Event

Once we were satisfied with the structural integrity of LANTIRN in the carrier environment, we moved on to the functional carrier suitability evaluation.

This series of test events was very similar to those used in the structural CVS. The key difference was that this time, they were performed using a LANTIRN-capable fleet aircraft and a fully functional pod.

We started early, and after 6 Cats, 5 Traps, 9 Touch-and-Go's, 2 Goodyear tires and a couple of Power Bars, we were done by 3:30 in the afternoon!

To the best of my knowledge, this is the first time a functional CVS was completed on an F-14 in 1 day. And it was all the more impressive because Al Poindexter up front was fighting a 90° crosswind all day that was right on the 10 kt test limit.

This next video clip is from the centerline camera at the test site. It begins with the high sink end-point of 1290 fpm (21.5 fps), shows two of the roll/yaw points, and the 20 ft off-center engagement (which was actually 18.9 ft) .

(VIDEO #2)

- ...took a 6° glide slope to get this point; watch the right wingtip...
- We use a very high-tech method of marking the 20 ft lateral aimpoint: special Mil-Spec white Navy Toilet Paper wrapped around the arresting cable...

Up-and-Away Loads and Vibration

Photo 14

- 8 Flights; 13.0 Flt Hrs
- Instrumented Pax F-14B, Pod, and Hardback
- Test Limits
 - +6.5 g
 - 1.6 TMN / 720 KIAS

Photo 15

After our instrumented aircraft had completed the Structural Carrier Suitability testing, it was quickly pressed into service for the Loads and Vibration work.

The first phase of this test was flown with external accelerometers on the LANTIRN pod in order to correlate measured vibratory loads with predicted values. Once good correlation was demonstrated, the external accels were removed and the remainder of the test program was devoted to structural envelope expansion. The final phase evaluated the effects of external fuel tanks, and determined that their contribution was negligible.

Overall, the structural integrity of the pod and mounting hardware was shown to be satisfactory within the full F-14 maneuvering envelope up to 1.6 TMN and 720 indicated, which are the existing speed restrictions on the LANTIRN pod when in the stowed position (1.2 TMN with the windows exposed).

An interesting sidenote is that, as a fallout of an ongoing F-14 mishap investigation, the day after these tests were completed, all F-110 powered F-14's (F-14B's and D's) were restricted to emergency-only use of afterburner. Had we not completed the high mach and high q testing when we did, it would have been very difficult to resume this test several months later, and the fleet may have had to live with a restricted flight clearance for some time.

By the way, the Up-and-Away Loads test team was made up of Lt Scott Kelly and Paul Conigliaro, who spoke to you earlier about the DFCS program.

Functional Tests

Photo 16
(A/C 206)

Time does not allow me to do justice to the many tests that fell under this category. But excluding the functional carrier suitability, maintenance and ferry flights, the bottom lines were 21 flights and 31.7 flight hours, all conducted in just over a month, and all on the same LANTIRN pod (Navy Pod #3).

As alluded to earlier in the presentation, much of this time was spent in software verification and basic functional checks, but there were several other important activities..

We measured the laser boresight accuracy and the minimum resolvable temperature difference (MRAT) both before and after the carrier suitability period to check for any degradation in performance. We flew 5 dedicated flights to verify the accuracy of the ballistics algorithms in the pod for GBU-10, 12, 16, and 24, and checked the new cockpit controls and displays for NVG compatibility.

Our final end-to-end check of the system was the successful delivery of a Laser-Guided Training Round to the Dare County range in North Carolina.

The following series of video excerpts were taken from several of the functional performance test flights.

(VIDEO #3)

Overall Results

Resolved:

- LANTIRN Pod, Hardback, and Adapter Demonstrated Adequate Structural Margins for Carrier Operations
- Functional Performance is Suitable for Carrier Operations

In Work:

- GPS/INS Filtering
- LTS Ballistics Algorithms
- LCP Faceplate (E3)
- Focus

Generally we were very happy with the performance of the system. We were pleased to discover that the LTS will easily withstand the structural demands of aircraft carrier launch and recovery operations, as well as the F-14 vibro-acoustic environment.

There are several issues that will require resolution or at least further study.

- The pod software for the GPS / INS blending scheme was not operating properly during the course of our testing, but a software patch was recently implemented and we believe this problem is now resolved.
- Although the ballistics algorithms provided an acceptable release point for straight and level through shallow dive deliveries, some improvement may be necessary at higher dive angles. The data are still under review and we're working with the contractor to resolve this.
- After receiving the NVG lighting mod, the LANTIRN Control Panel demonstrated an RF vulnerability during E-cubed testing that was traced to the composite faceplate on the LCP, and a new faceplate material is now under study.
- Lastly, we noticed a slight degradation in the focus quality in Narrow FOV on Navy Pod #3 over the course of our testing, and we're awaiting the results of further bench checks to verify this.

At this point, we don't consider any of these to be showstoppers, and the opinion of the test team is that the system is ready for deployment.

Conclusions

The F-14 LANTIRN Targeting System is:

- Carrier-Suitable
- F-14 Compatible
- Nearly RIO-Proof!

Bottom Lines: This system will work on the ship, it will work on the F-14, and it is very easy to operate.

If a Commander can figure it out in two flights, rest assured that an average Fleet Lieutenant will have it wired in 30 minutes!

Lessons Learned

Keys to Success...

- Co-Location, Co-Location, Co-Location
- Communication & Teamwork
- Flexibility
- "Better" is the Enemy of "Good Enough" !!

Before I close, I wanted to mention several things that I thought were critical to the success we enjoyed in this project.

For the first bullet, I put my own spin on a phrase stolen from the real estate world. We found it to be absolutely essential to have all the key players, government and contractor, under the same roof. I can't tell you how many times we resolved critical problems or avoided them altogether by being able to quickly apply the right talent to the issue.

This leads to my second point: There is no way to successfully complete a complex, time-critical test program without full and open communication between all parties. No government-only meetings, no closed-door discussions. Each individual must work as part of the team and focus on winning the ball game, not outscoring his teammates.

Next, as everyone knows who has been in the flight test business longer than one day, events rarely proceed exactly according to plan. Flexibility is essential. Without constantly working on backup plans and alternatives, the test team loses momentum, and eventually time, at the first sign of trouble.

And lastly, in this program, if the Navy had gone with a fully integrated FLIR package for the F-14 with all the bells and whistles, it may have been a little "better", but would likely have cost twice as much and delayed fleet introduction by 2 yrs. The F-14 LANTIRN Targeting System is exactly what the fleet user needs now, and it will add tremendous new capability to the carrier battle group.

Questions ?

Photo 17

Photo 18

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